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13. ABSTRACT (Maximum 200 words)

A snapshot imaging spectrometer known as the Computed Tomography Imaging Spectrometer (CTIS), operating at 15 frames per second, measured the PAC III intercept of a Hera at White Sands Missile Range (WSMR) on March 31, 2001. As in computed tomography, the collected data must be processed to produce the spectral images. A technical report describes the collection technique, the reconstruction techniques, and the resulting spectral images. A paper emphasizing the hyperspectral aspect of CTIS was written and presented. A paper emphasizing the insight gained about the intercept from the CTIS instrument was written and presented. The reconstructed data was submitted in computer-readable form to the sponsoring agency, Space and Missile Defense Comand, SMDC-TSC.

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Final Progress Report

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Visible Spectrometer Measurements of the PAC III Intercept of Hera at WSMR on 31-Mar-2001: Final Report (submitted September, 2002)

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Statement of the problem studied

This grant supported snapshot imaging spectrometry of an transient event of interest to missile defense: a kinetic kill of a Hera drone by a PAC-III interceptor over White Sands Missile Range (WSMR). The technique for time-resolved imaging spectrometry was invented at the Optical Detection Laboratory of the Optical Sciences Center at the University of Arizona. Known as Computed Tomography Imaging Spectrometer (CTIS), the technique uses the mathematics of computed tomography to resolve projections of a three-dimensional spatial-spectral data cube. Because the spatial-spectral data for a scene is collected during each frame of a digital camera, the spatial-spectral data is time-resolved at the frame rate of the camera.

Summary

On the morning of 31-March-2001 over White Sands Missile Range (WSMR), a PAC III missile intercepted a Hera launched from the north-north-west (Ft. Wingate). The Hera consisted of a re-entry vehicle still attached to its final stage.

In accordance with the U.S. Army Research Office (ARO) Grant No. DAAD19-01-1-0471, the intercept was recorded by a visible non-scanning imaging spectrometer known as Computed Tomography Imaging Spectrometer (CTIS). The spectrometer was co-aligned with an infrared camera on a tracker at the **Phil Site** on WSMR. **THE PHIL SITE WAS ABOUT 35 KM SLANT RANGE FROM THE INTERCEPT.** The tracker was operated by a team headed by Tony Blea, WSMR. CTIS was operated by a team from the Optical Detection Laboratory at the Optical Science Center of the University of Arizona. Monitoring the activities from the Space Missile Defense Command (SMDC) were Tom Hamilton and Bob.McMillan@SMDC.army.mil.

CTIS simultaneously records spatial and spectral information about a color scene by diffractively dispersing an 2-d field stop in two orthogonal directions. The zeroth diffractive order records a grayscale view of the color scene and nominally spans 79x79 pixels at the center of the grayscale sensor array. In a grayscale view, the entire spectrum of each spatial position is integrated by its corresponding pixel in the center order. Pixels within non-zero diffractive orders record a different part of the spectrum for different spatial positions.

A CTIS reconstruction produces an (x,y,λ) spatial-spectral data consistent with the pixel measurements. The spatial-spectral data consists of 79x79 spatial positions, each of which has associated with it a spectrum. The spectrum consists of 76 bands of 4nm width centered on wavelengths from 420 to 720 nm. The spectrum was reconstructed for 16 frames: one before and 15 after the intercept. For this intercept, CTIS recorded frames at 15 Hertz with a 8 ms integration time (12% duty cycle).

The intercept was viewed against a clear sky, facilitating reconstruction. After subtracting the sky's contribution, a reconstruction yielded spatial-spectral data for the intercept. The reconstruction data show signals with two broad spectral shapes. One shape is dubbed ***solar*** since it peaks in the visible. The other shape is dubbed ***thermal*** since it peaks in the infrared. The solar spectra reflects from the missiles before impact and from debris after impact. The thermal source is created at impact. After a brief (~150 ms) delay, the thermal source separates into two sources. **THE SECOND SOURCE SUBSEQUENTLY (ABOUT 100 MS DELAY) BRIEFLY INCREASES ITS THERMAL PROFILE THEN RAPIDLY DECAYS. THE LARGER THERMAL SOURCE DECAYS SOMEWHAT SLOWER BUT LOSES ITS THERMAL PROFILE OVER THE COURSE OF A SECOND.**

Computer-readable media containing the spatial-spectral data is available for further analysis for approved purposes. Contact Bob.McMillan@SMDC.army.mil (256)955-5418 for instructions on obtaining the files described in this report.

Publications and technical reports

A technical report and two presentations resulted from the data collected under this grant:

(a) No peer-reviewed papers resulted.

(b) Two papers were published in proceedings of meetings
George, J.D. et al., "Snapshot Imaging Spectrometer Measurements of PAC III Intercept", *Proceedings of the Workshop on Multi/Hyperspectral Technology and Applications*, rescheduled from September 2001 to February 2002.
George, J.D. et al., "Snapshot Imaging Spectrometry of PAC III Intercept of Hera", *Missile Defense Sensors, Environments and Algorithms (MD-SEA) Military Sensing Symposium (MSS),* February 2002.

(c) No papers were presented without proceedings.

(d) No unpublished manuscripts were submitted.

(e) George, J.D. and J.P. Garcia,**Visible Spectrometer Measurements of the PAC III Intercept of Hera at WSMR on 31-Mar-2001 (Revised September, 2002)**

Scientific Personnel

A number of scientific personnel contributed to the collection, analysis, and presentation of the data. None were employed full-time on the grant.

University of Arizona, Optical Sciences Center:
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James D. George, Jr.
Dan O'Connell
Curtis E. Volin

White Sands Missile Range
Anthony Blea

Space Missile Defense Command
Tom Hamilton
Robert McMillan

Inventions

No inventions arose from this grant.

Bibliography

See Publications and Technical Reports above.

Appendices

No appendices are a part of this final progress report.